Appendix 4-E (Performance Chapter)
Laboratory Test Procedures and Performance Data

Adhesive Lamination

Purpose

The purpose of this test is to measure the bond strength of the adhesive layer of the lamination to the ink. The adhesive lamination test is based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

Force measurement instrument
#6 Meyer bar
Oven
Adhesive (Morton's Lamal HSA or Adcote 333)

Procedure

1. Make a print of ink to be tested on designated stock using a #6 Meyer bar.

2. Dry print in oven at 180°F for 30 seconds.

3. Apply a second down of adhesive (Morton's Lamal HSA or Adcote 333) using a #6 bar.

4. Dry the adhesive at 120°F for 30 seconds.

5. Place the stock to which the ink is to be laminated in contact with the printed sample. Use a flexographic hand proofer to apply pressure to the lamination and to remove any trapped air.

6. Place the sample in a 180°F oven for 45 seconds to cure the adhesive.

7. Let sample age for a minimum of 24 hours before testing.

8. Cut a one-inch test strip from the laminated sample and use the force measurement instrument to determine the force (in kilograms) which is necessary to separate the two pieces of stock.

Results

Delamination tests were done in the machine direction of the laminated film. The delamination force was the average of five measurements. Samples were cut from one location during the run as indicated by the following symbol:

x = thirty minutes into run

Results appear in Chapter 4.

Block Resistance

Purpose

The purpose of the block resistance test is to check the bond of the ink to the substrate when heat and pressure are applied. The block resistance test is based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

I.C. Block Tester
Calibrated compression springs
Oven
Humidity-controlled environment (if not available, conditions should be reported)

Procedure

1. The adhesion of the ink is tested two ways: "face to face" (printed side to printed side) and "face to back" (printed side to unprinted side). "Back to back" (unprinted substrate on unprinted substrate) should be tested as the control.

Only surface printed samples are tested "face to face." The original protocol stated, "The test should be conducted at 5 pounds per square inch (psi) for 16 hours at 80% relative humidity. These humidity conditions must be met in order to properly interpret the results." However, the actual tests were conducted at 100 psi for 8 hours at 43% humidity in a 120°F oven.

Surface and lamination printed samples are tested "face to back." The original protocol stated, "The standard test should be conducted at 50 psi for 16 hours at 80% relative humidity. If 80% relative humidity cannot be met, use 125 psi at 120°F at ambient humidity." However, the actual tests were conducted at 100 psi for 8 hours at 43% humidity in a 120°F oven.

2. Test prints should be two inches wide by six inches long. The minimum size is two inches wide by two inches long.

3. Place test prints (face-to-face, face-to-back, or back-to-back) on the base of the block tester immediately after printing and drying.

4. Insert the centering place without disturbing the position of the test prints.

5. Select a calibrated compression spring, depending on the pressure required.

6. Place the spring (bottom in centering plate opening) into the assembly and tighten to the desired pressure (indicator and scale attached to spring).

7. Place the block tester in an environment with the specified humidity.

8. Remove the print and separate it carefully to observe the tendency to block.

9. When the test print is on vinyl or highly plasticized film, check the block test after the recommended period of time, then place it back in the test chamber and check it again after several days. Blocking may occur after a prolonged period of time due to plasticizer migration.

Results

The OPP substrate from sites 1, 4, 9, and 10 was tested in the in the pre-laminated state, to simulate rewind conditions that it would be subjected to prior to converting. The results are reported on a scale from 0 to 5 as described in Table 4-E.1.

Table 4-E.1 Description of Block Resistance Results

Score	Block Resistance Result	Description
0	No blocking	No adhesion or cohesion between contiguous surfaces, which slide or peel freely upon one another. Surfaces of specimens are not marred.
1	Slight cling	A slight "ticking" can be heard as the samples are carefully peeled apart, but there is no visible marring of the surface.
2	Cling	There is a noticeable adhesion between adjacent surfaces or a visual marring of the surfaces but no distortion of webs or offset of printing inks, lacquers, or other coatings.
3	Slight blocking	Slight adhesion, adjacent surfaces do not slide or peel freely, but do with frictional pressure. Surface of specimen may show very slight evidence of web distortion or marring of the coating or transfer of ink or coating to the immediate contact surface of next specimen.
4	Considerable blocking	Adhesion or cohesion of contiguous surfaces. Layers may be separated with difficulty. Surfaces will be distorted, marred, or partially destroyed showing ink, lacquer, or coating transfer to the immediate contact surface of next specimen. Paper based materials will show loss of fiber. Synthetics may or may not display surface mar.
5	Complete blocking	Blocking to the extent of a complete seal or weld between adjacent surfaces which cannot be separated without destructing the specimen.

For the testing of the samples printed at the performance demonstration facilities and at Western Michigan University, samples were cut from two locations during the run length as indicated by location identification symbols as follows:

w = beginning of run
z = end of run

Table 4-E.2 shows the block resistance of samples from each site. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.2 Block Resistance For Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	F-F/ F-B[b]	Result[c]	Score[c]
Solvent-based	LDPE	#S2	5	w	F-F	slight blocking	3
					F-B	slight blocking	3
				z	F-F	slight cling	1
					F-B	slight cling	1
			7	w	F-F	considerable blocking on blue	4
					F-B	considerable blocking on blue	4
				z	F-F	slight blocking	3
					F-B	considerable blocking on blue	4
			L5[d]	w	F-F	slight blocking	3
					F-B	slight cling	1
				z	F-F	slight blocking	3
					F-B	slight blocking	3
	PE/EVA	#S2	5	w	F-F	slight cling	1
					F-B	considerable blocking	4
				z	F-F	slight cling	1
					F-B	slight blocking on green	3
			7	w	F-F	slight blocking	3
					F-B	considerable blocking on blue	4
				z	F-F	slight blocking	3
					F-B	considerable blocking	4
			L7				
	OPP	#S1	9B	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	considerable blocking on blue	4
		#S2	10	w	F-F	slight blocking	3
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight blocking	3
			L4	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight cling	1

Ink System	Film	Product Line	Site	Location of Sample[a]	F-F/ F-B[b]	Result[c]	Score[c]
UV	LDPE	#U2	6	w	F-F	slight cling	1
					F-B	considerable blocking	4
				z	F-F	slight cling	1
					F-B	considerable blocking	4
	PE/EVA	#U2	6	w	F-F	slight cling	1
					F-B	considerable blocking	4
				z	F-F	slight cling	1
					F-B	slight cling	1
		#U3	8	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight cling	1
UV (no slip)	LDPE	#U1	11	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight cling	1
Water-based	LDPE	#W3	2	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight cling	1
			3	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight blocking on green	3
			L1	w	F-F	slight blocking	3
					F-B	slight blocking	3
					F-F	slight cling	1
					F-B	slight cling	1
	PE/EVA	#W3	2	w	F-F	slight cling	1
					F-B	slight blocking on blue	3
				z	F-F	slight cling	1
					F-B	slight cling	1
			3	w	F-F	slight cling	1
					F-B	slight cling	1
				z	F-F	slight cling	1
					F-B	slight cling	1
			L6	w	F-F	slight cling	1
					F-B	slight blocking	3
				z	F-F	slight cling	1
					F-B	slight blocking	3

Ink System	Film	Product Line	Site	Location of Sample[a]	F-F/ F-B[b]	Result[c]	Score[c]
	OPP	#W1	4	w	F-F	considerable blocking	4
					F-B	considerable blocking	4
				z	F-F	considerable blocking	4
					F-B	considerable blocking	4
Water-based	OPP	#W2	1	w	F-F	considerable blocking	4
					F-B	slight blocking	3
				z	F-F	considerable blocking	4
					F-B	slight cling	1
			L3	w	F-F	slight blocking	3
					F-B	slight blocking	3
				z	F-F	slight blocking	3
					F-B	slight cling	1
		#W4	9A	w	F-F	considerable blocking	4
					F-B	slight cling	1
				z	F-F	considerable blocking	4
					F-B	slight cling	1
			L2	w	F-F	slight blocking	3
					F-B	slight cling	1
				z	F-F	slight blocking	3
					F-B	slight cling	1

[a]Samples were taken at two locations from the printed sample:
w = beginning of run
z = end of run

[b]Samples were tested in two ways:
F-F = face to face (printed substrate to printed substrate)
F-B = face to back (printed substrate to unprinted substrate)

[c]The score is a number corresponding to the test result based on the following scale:
no blocking = 0
slight cling = 1
cling = 2
slight blocking = 3
considerable blocking = 4
complete blocking = 5

[d]"L" indicates data from a laboratory run.

See Table 4-E.1 for a complete description.

CIE L*a*b*

Purpose

The purpose of the CIE (International Commission on Illumination) L*a*b* test is to measure the reflected light and calculate a numerical value for the light/darkness, hue, and chroma of a printed color. The CIE L*a*b* test is based on methods developed by Western Michigan University.

Equipment

Spectrophotometer/colorimeter (Datacolor Spectraflash 600)

Procedure

1. Measure the CIE L*a*b* values using the Datacolor Spectraflash 600. Operate the colorimeter in accordance with the manufacturer's specifications.

2. Measurements will be performed using the Small Area View (SAV) port, so calibrations should also be made to this port size. Following the instructions on the computer screen, calibrate to the black cavity holding it over the port. Then attach the white standard 529 to the arm and calibrate according to the instructions.

3. Measure the samples using the SAV port size. Two samples are to be taken from four locations of the run. All three substrates will be tested (LDPE, PE/EVA, and OPP). Generally, select the mode for CIE L*a*b* and place the sample area at port. Follow the instructions on the screen to proceed with the testing.

4. Take readings of solid ink densities at several areas of the specimen surface to obtain an indication of uniformity.

5. Measure each sample on both sides of the sheet for each color. The instrument will automatically take five measurements and report the average as one value.

Results

CIE L*a*b* values were measured in the laboratory with samples collected from each site. Samples were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Table 4-E.3 shows the CIE L*a*b* measurements for these samples. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
Solvent-based	LDPE	#S2	5	w	magenta	46.81	59.05	-5.10	x	magenta	46.34	58.61	-3.03
					cyan	59.71	-40.72	-26.94		cyan	58.69	-39.99	-27.68
					green	53.46	-49.05	29.66		green	52.00	-48.27	28.43
					blue	39.57	2.75	-49.81		blue	38.94	4.29	-49.91
				y	magenta	48.30	57.32	-6.33	z	magenta	46.82	58.67	-4.87
					cyan	60.41	-40.17	-25.94		cyan	60.48	-40.35	25.98
					green	54.87	-48.20	30.38		green	53.33	-48.85	29.77
					blue	37.32	6.32	-50.93		blue	36.46	7.64	-50.67
			#7	w	magenta	50.44	54.92	-8.45	x	magenta	48.58	55.49	-4.91
					cyan	62.12	-38.74	-23.57		cyan	61.02	-39.20	-24.42
					green	63.90	-38.92	31.15		green	62.57	-40.98	32.19
					blue	43.86	-2.34	-45.69		blue	42.25	1.02	-47.05
				y	magenta	49.80	54.95	-6.91	z	magenta	51.29	52.57	-7.45
					cyan	60.67	-39.37	-24.86		cyan	63.19	-38.07	-22.73
					green	60.94	-43.01	32.33		green	67.27	-34.46	30.01
					blue	41.04	1.49	-48.26		blue	42.58	-0.05	-46.81
			L5[b]	w	green	53.54	-47.45	28.56	x	green	66.57	-36.54	30.52
				y	not sampled				z	green	65.09	-38.19	31.21

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
	PE/EVA	#S2	5	w	magenta	51.94	50.92	-0.09	x	magenta	52.53	52.18	-2.41
					cyan	61.82	-27.62	-37.92		cyan	62.41	-28.84	-37.96
					green	58.18	-56.64	34.24		green	57.22	-56.62	33.88
					blue	37.61	15.70	-56.09		blue	38.30	15.26	-57.75
				y	magenta	54.08	47.24	1.47	z	magenta	57.90	40.56	-0.49
					cyan	61.49	-29.06	-38.91		cyan	62.95	-24.43	-35.65
					green	55.68	-53.52	30.48		green	56.02	-53.53	30.66
					blue	35.32	18.08	-57.43		blue	36.14	16.78	-57.70
Solvent-based	PE/EVA	#S2	7	w	magenta	52.05	51.69	-3.39	x	not sampled			
					cyan	61.97	-30.98	-36.12					
					green	67.66	-46.77	31.92					
					blue	38.17	13.76	-53.99					
				y	not sampled				z	magenta	49.91	56.31	-4.38
										cyan	60.47	-32.37	-38.11
										green	67.71	-47.19	32.25
										blue	39.37	12.46	-53.74
			L7	w	green	65.08	-37.95	31.41	x	green	65.57	-36.25	31.36
					cyan	63.68	-28.18	-38.08		cyan	62.79	-29.25	-36.79
				y	not sampled				z	green	65.09	-38.16	31.21
										cyan	63.42	-28.95	-37.46

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
	OPP	#S1	9B	w	magenta	52.62	51.76	-3.70	x	magenta	50.91	52.69	-4.77
					cyan	60.46	-37.66	-26.45		cyan	60.38	-37.29	-26.26
					green	64.43	-35.65	30.61		green	64.68	-35.43	30.04
					blue	47.80	-5.45	-39.48		blue	48.71	-6.12	-38.04
				y	not sampled				z	magenta	52.40	52.16	-3.41
										cyan	59.06	-37.48	-28.35
										green	65.18	-34.52	30.62
										blue	46.41	-4.07	-41.13
		#S2	10	w	magenta	66.76	29.93	-5.30	x	magenta	67.18	29.04	-5.74
					cyan	71.08	-26.11	-12.23		cyan	71.20	-26.64	-12.13
					green	55.72	-48.65	29.45		green	57.11	-44.59	28.27
					blue	39.31	2.28	-47.28		blue	41.27	3.59	-43.80
				y	magenta	68.22	28.71	-4.87	z	magenta	65.87	32.22	-7.01
					cyan	71.05	-27.89	-12.55		cyan	70.09	-29.05	-13.76
					green	56.07	-47.92	29.87		green	56.26	-47.57	29.98
					blue	39.19	2.59	-47.38		blue	40.26	1.58	-45.98
			L4	w	green	70.87	-33.35	31.11	x	green	70.16	-35.22	32.07
				y	not sampled				z	green	68.54	-38.30	33.95

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
UV	LDPE	#U2	6	w	magenta	42.11	48.82	11.17	x	magenta	42.11	49.73	10.84
					cyan	60.94	-37.61	-23.79		cyan	61.65	-37.44	-23.34
					green	65.40	-51.71	32.99		green	65.06	-50.43	33.35
					blue	40.36	2.63	-44.68		blue	40.76	1.84	-44.67
				y	magenta	42.02	49.46	11.56	z	magenta	48.97	48.12	10.03
					cyan	61.38	-37.14	-23.52		cyan	60.72	-38.14	-24.38
					green	65.78	-50.83	32.90		green	65.93	-50.06	32.60
					blue	40.63	2.24	-44.79		blue	40.54	2.28	-44.79
	PE/EVA	#U2	6	w	magenta	46.82	55.69	3.11	x	magenta	46.35	55.23	5.88
					cyan	60.61	-30.79	-38.40		cyan	61.21	-30.22	-38.54
					green	65.39	-58.63	31.76		green	64.14	-57.25	31.55
					blue	38.39	11.49	-52.13		blue	38.93	11.65	-49.91
				y	magenta	48.54	51.93	4.59	z	magenta	48.70	52.53	2.44
					cyan	60.77	-30.70	-38.71		cyan	60.52	-30.88	-38.67
					green	64.18	-57.78	31.66		green	64.18	-57.99	31.95
					blue	39.33	10.91	-50.18		blue	38.58	11.15	-49.45
		#U3	8	w	magenta	54.14	52.66	-2.81	x	magenta	51.45	56.13	-1.44
					cyan	63.48	-27.03	-36.39		cyan	62.51	-26.58	-36.70
					green	72.45	-51.68	5.85		green	70.12	-55.25	6.88
					blue	49.08	8.48	-46.97		blue	48.04	8.59	-46.95
				y	not sampled				z	magenta	54.05	51.72	-2.97
										cyan	61.14	-28.06	-37.85
										green	70.22	-54.56	6.78
										blue	48.79	8.29	-46.38

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
UV (no slip)	LDPE	#U1	11	w	magenta	54.18	46.31	-4.60	x	magenta	53.37	48.78	-4.05
					cyan	60.44	-32.03	-22.90		cyan	60.08	-32.78	-24.64
					green	64.56	-54.70	10.24		green	64.09	-56.67	10.51
					blue	34.90	15.02	-50.88		blue	34.85	14.39	-51.32
				y	magenta	51.64	50.84	-5.14	z	magenta	51.64	49.31	-5.01
					cyan	58.96	-34.73	-25.38		cyan	60.02	-33.54	-24.74
					green	63.59	-58.06	10.88		green	63.20	-58.17	11.16
					blue	34.32	15.93	-51.98		blue	34.31	16.21	-52.35
Water-based	LDPE	#W3	2	w	magenta	51.52	50.03	-0.48	x	magenta	51.12	50.45	-1.05
					cyan	54.65	-25.74	-38.83		cyan	55.59	-26.05	-38.44
					green	63.34	-51.49	36.40		green	63.63	-50.78	35.99
					blue	34.12	16.15	-51.01		blue	34.51	15.58	-50.67
				y	magenta	50.18	51.39	-0.77	z	magenta	52.88	50.32	-4.71
					cyan	55.38	-25.69	-38.55		cyan	59.90	-34.29	-26.92
					green	63.28	-50.47	35.41		green	58.98	-51.87	29.54
					blue	34.56	15.37	-51.11		blue	33.26	16.95	-46.48
			3	w	magenta	52.63	53.02	-6.74	x	magenta	52.54	50.84	-7.85
					cyan	63.48	-32.33	-22.45		cyan	62.63	-34.43	-23.86
					green	62.00	-54.24	37.49		green	61.66	-55.06	38.24
					blue	33.51	16.91	-51.59		blue	33.56	17.72	-50.93
				y	magenta	52.36	51.41	-7.88	z	magenta	52.29	49.96	-6.18
					cyan	65.89	-29.05	-19.15		cyan	64.38	-32.32	-21.36
					green	62.07	-54.09	37.37		green	61.34	-54.58	37.49
					blue	33.41	18.35	-50.44		blue	33.23	18.62	-50.04
			L1	w	green	68.96	-43.96	31.91	x	green	68.64	-43.96	32.44
					not sampled				z	green	67.56	-44.95	32.64

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
	PE/EVA	#W3	2	w	magenta	54.16	52.02	-0.81	x	magenta	57.12	44.64	-0.61
					cyan	58.72	-22.49	-40.88		cyan	58.79	-23.84	-40.54
					green	63.04	-57.39	33.24		green	61.58	-59.99	35.40
					blue	37.39	16.33	-48.76		blue	32.72	20.43	-51.31
				y	magenta	54.22	51.16	-1.98	z	magenta	55.37	46.26	-0.78
					cyan	57.81	-21.33	-40.99		cyan	58.97	-20.70	-38.74
					green	63.15	-57.23	33.39		green	61.49	-58.03	34.18
					blue	32.38	20.89	-49.57		blue	32.98	20.34	-47.44
Water-based	PE/EVA	#W3	3	w	magenta	52.43	56.66	-1.30	x	magenta	53.95	55.12	-2.64
					cyan	61.74	-28.56	-39.27		cyan	62.75	-26.86	-37.87
					green	61.80	-60.18	35.32		green	62.98	-58.85	34.27
					blue	33.13	20.45	-48.64		blue	35.13	19.36	-50.23
				y	magenta	54.44	54.37	-2.59	z	magenta	55.28	54.17	-3.63
					cyan	61.55	-28.31	-39.73		cyan	61.96	-28.71	-39.36
					green	61.31	-59.85	35.04		green	62.98	-59.92	35.06
					blue	34.96	19.25	-49.28		blue	36.82	16.71	-53.41
			L6	w	green	69.76	-53.37	30.45	x	green	70.23	-50.37	28.23
					cyan	64.85	-29.29	-36.93		cyan	65.79	-28.72	36.45
				y	not sampled				z	green	71.22	-51.03	29.15
										cyan	63.68	-28.81	-38.08

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
	OPP	#W1	4	w	magenta	49.29	52.86	-3.68	x	magenta	48.53	48.22	-4.52
					cyan	58.59	-30.91	-25.31		cyan	60.57	-32.81	-24.62
					green	53.50	-54.28	31.02		green	53.51	-54.29	31.16
					blue	39.52	1.25	-45.51		blue	39.50	1.08	-46.23
				y	magenta	50.05	50.20	-3.96	z	magenta	49.02	53.58	-4.02
					cyan	60.21	-33.05	-25.00		cyan	58.47	-35.07	-27.34
					green	52.90	-54.39	31.03		green	53.36	-55.34	31.72
					blue	40.52	0.72	-44.19		blue	39.45	2.07	-45.99
		#W2	1	w	magenta	50.58	50.16	-0.26	x	magenta	49.78	46.08	3.69
					cyan	58.33	-31.15	-27.22		cyan	56.87	-31.51	-28.55
					green	63.99	-57.96	44.50		green	63.51	-57.74	44.05
					blue	29.81	17.42	-38.53		blue	30.36	15.12	-37.15
				y	magenta	49.93	47.93	2.99	z	magenta	50.39	47.12	3.35
					cyan	57.63	-29.06	-27.14		cyan	56.78	-31.14	-28.55
					green	64.74	-57.46	44.15		green	64.51	-57.46	44.95
					blue	30.43	15.05	-37.04		blue	30.16	15.00	-36.46
			L3	w	green	73.10	-32.01	25.16	x	green	72.32	-32.99	25.36
					not sampled				z	green	72.31	-33.04	25.11

Table 4-E.3 CIE L*a*b* Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	L*	a*	b*	Location of Sample[a]	Color	L*	a*	b*
Water-based	OPP	#W4	9A	w	magenta	48.84	53.10	3.72	x	magenta	47.67	53.31	6.09
					cyan	57.76	-36.13	-30.30		cyan	57.55	-36.02	-30.47
					green	62.18	-52.99	31.33		green	60.77	-54.17	32.18
					blue	42.38	-2.15	-45.35		blue	41.95	-1.11	-45.58
				y	not sampled				z	magenta	49.08	50.66	2.67
										cyan	58.08	-35.07	-29.12
										green	61.23	-52.82	32.79
										blue	42.17	-0.87	-43.77
			L2	w	green	66.08	-44.94	28.90	x	green	66.00	-46.12	28.95
					not sampled				z	green	66.88	-42.01	26.93

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]"L" indicates data from a laboratory run.

Coating Weight

Purpose

The purpose of this test was to evaluate the coating weight of the printed substrate. Coating weight is the weight of the ink film layer coverage on a substrate. The coating weight test was based on methods developed by Western Michigan University.

Equipment

Conventional laboratory oven
Scale (accurate to 0.001 ounces)

Procedure

1. Scan each color separation to determine the percent of ink coverage per square centimeter of one printed repeat (16" x 20").

2. Determine the total area of printed substrate (in square centimeters).

3. Take 50 samples from the middle of the run (30 minutes into the run).

4. Cut 25 samples of the solid 100% ink coverage test blocks for each color printed. Measure and record the area of the ink blocks in square centimeters.

5. Cut equal areas of unprinted film (matching the areas to those cut out in step 4 above).

6. Dry the solvent-based and water-based ink samples in the oven at 150°F for one hour to remove any remaining solvents. The UV ink samples do not need to be dried in the oven.

7. For each color, weigh the two groups of 25 samples (printed and unprinted) separately. Divide the total weights of each group by 25 to determine the weight of the ink per area for each signature. Using the weight per square centimeter, calculate the total dry ink coat weight for the total linear footage for the press run.

Results

Samples were cut from a standard location during the run length as indicated by the following symbol:

x = 30 minutes into run

Only one location was needed for testing, since there was no significant difference between the various locations (e.g., the beginning, middle, and end of the run). The solid 100% ink coverage blocks that served as test samples were printed with green, blue, and white inks. Table 4-E.4 shows the coating weights for these ink colors at different sites. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.4 Coating Weight Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Color	Weight Per Area (1×10^{-4} g/cm^2)
Solvent-based	LDPE	#S2	5	blue	1.88
				green	2.99
				white	2.33
			7	blue	1.65
				green	0.97
				white	2.08
			L5*	green	4.33
				white	6.68
	PE/EVA	#S2	5	blue	1.22
				green	1.39
			L7		4.33
	OPP	#S1	9B	blue	1.33
				green	0.94
				white	2.75
		#S2	10	blue	1.15
				green	1.47
				white	1.73
			L4	green	1.05
				white	1.79
UV	LDPE	#U2	6	blue	1.92
				green	2.77
				white	3.51
	PE/EVA	#U2	6	blue	4.50
				green	3.00
		#U3	8	blue	1.64
				green	1.20
UV (no slip)	LDPE	#U1	11	blue	1.94
				green	2.98
				white	3.71

Table 4-E.4 Coating Weight Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Color	Weight Per Area (1×10^{-4} g/cm^2)
Water-based	LDPE	#W3	2	blue	1.79
				green	1.58
				white	2.39
			3	blue	1.43
				green	1.20
				white	2.32
			L1	green	2.14
				white	2.42
	PE/EVA	#W3	2	blue	1.80
				green	1.77
			3	blue	2.23
				green	1.52
			L6	green	4.71
Water-based	OPP	#W1	4	blue	1.59
				green	2.05
				white	3.90
		#W2	1	blue	1.70
				green	2.04
				white	3.58
			L3	green	1.03
				white	1.35
		#W4	9A	blue	0.87
				green	0.83
				white	2.31
			L2	green	0.88
				white	1.21

* "L" indicates data from a laboratory run.

Coefficient of Friction

Purpose

The purpose of the coefficient of friction (COF) test is to determine the resistance to slide of a printed sample. The COF of printed ink on film is important when converting the printed rolls and meeting the requirements of the end product. This test is based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

Friction/Peel Tester Thwing Albert
Sled (standard weight block — 200 grams)

Procedure

1. Press the COF button on the display unit to select the friction test.

2. Press the sled button repeatedly until the sled weight at display matches the weight of the sled used.

3. Press the time button repeatedly until the desired duration of time is displayed (20 seconds).

4. Press the zero load switch to provide zero reading.

5. Use the test, stop, and return switches to position the load cell at the starting point for the test. Loosen the Left Limit Switch Actuator and slide it next to the load cell to set the left-hand limit motion.

6. Press the return switch to place the load cell at the starting point.

7. Secure one strip of material to the test sled (face up).

8. Secure a second piece of material (face up) to the top plate of the lower chassis.

9. Attach the sled to the load cell and align it in the direction of travel.

10. Initiate the test by depressing the test switch. When a test is completed, the test results are displayed.

11. Record the static COF. Repeat the measurement five times.

12. Calculate the average COF measurements and use the standard Tappi T548 pm-90 test procedure to covert COF to angle of inclination.

Results

COF was measured in the laboratory using an Instron Tensile tester equipped with a friction sled. Sites 1, 4, 9, and 10 were not tested because the OPP substrate printed at these sites were laminated to another substrate. The COF was measured from samples taken from only one location (at the beginning of the run), as the COF was not expected to differ throughout the length of the run or across the web. The COF values were converted to angle of inclination.

Table 4-E.5 presents the data from all of the performance demonstration sites and laboratory runs. When a site number begins with an "L," the data were taken from a run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.5 Coefficient of Friction Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Condition[a]	Average Angle of Inclination (degrees)
Solvent-based	LDPE	#S2	5	blue/clear	26.6
				blue/blue	33.0
				green/clear	30.1
				green/green	40.0
				control	22.3
			7	blue/clear	24.2
				blue/blue	35.0
				green/clear	26.1
				green/green	35.8
				control	23.3
			L5[c]	green/clear	20.8
				green/green	30.6
				control	23.3
	PE/EVA	#S2	5	blue/clear	19.8
				blue/blue	32.2
				green/clear	31.4
				green/green	44.2
				control	16.7
Solvent-based	PE/EVA	#S2	7	blue/clear	19.6
				blue/blue	19.2
				green/clear	27.4
				green/green	25.2
				control	16.7
			L7	green/clear	
				green/green	
				control	

Table 4-E.5 Coefficient of Friction Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Condition[a]	Average Angle of Inclination (degrees)
UV	LDPE	#U2	6	blue/clear	30.1
				blue/blue	50.5
				green/clear	32.2
				green/green	57.2
				control	23.3
	PE/EVA	#U2	6	blue/clear	20.8
				blue/blue	21.8
				green/clear	20.8
				green/green	20.8
				control	16.7
		#U3	8	blue/clear	24.2
				blue/blue	24.2
				green/clear	27.6
				green/green	25.2
				control	16.7
UV (no slip)	LDPE	#U1	11	blue/clear	44.2
				blue/blue	60+[b]
				green/clear	29.6
				green/green	60+[b]
				control	45.0
Water-based	LDPE	#W3	2	blue/clear	29.2
				blue/blue	32.2
				green/clear	26.1
				green/green	33.8
				control	23.2
			3	blue/clear	22.3
				blue/blue	31.4
				green/clear	23.3
				green/green	27.4
				control	23.3
			L1	green/clear	34.2
				green/green	34.2
				control	23.3

Table 4-E.5 Coefficient of Friction Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Condition[a]	Average Angle of Inclination (degrees)
Water-based	PE/EVA	#W3	2	blue/clear	27.4
				blue/blue	40.0
				green/clear	22.3
				green/green	25.2
				control	16.7
			3	blue/clear	23.3
				blue/blue	30.6
				green/clear	19.8
				green/green	35.0
				control	17.2
			L6	green/clear	26.6
				green/green	40.0
				control	16.7

[a] Samples were tested under five different conditions:
blue/clear = printed substrate (blue ink) against unprinted substrate
blue/blue = printed substrate (blue ink) against printed substrate (blue ink)
green/clear = printed substrate (green ink) against unprinted substrate
green/green = printed substrate (green ink) against printed substrate (green ink)
control = unprinted substrate against unprinted substrate
[b] The angle of inclination was higher than 60 degrees.
[c] "L" indicates data from a laboratory run.

Density

Purpose

The purpose of the density test is to evaluate the degree of darkness (light-absorption) of a printed solid. The density test is based on methods developed by Western Michigan University.

Equipment

X-Rite 418 reflection densitometer

Procedure

1. Calibrate the densitometer. For all color references, follow calibration instructions obtained by pressing the function key and color key together. Using instructions on the instrument, set low (white standard) and high values (black standard) for each color, then read individual color patches as determined by the instrument. Verify calibration values for each standard patch and make adjustments as necessary.

2. Take two samples of each substrate (LDPE, PE/EVA, and OPP) from four locations on the press run.

3. The DEN function of the densitometer is used to take measurements. Take readings at 10 locations of the sample for each of the 5 colors in solid ink density areas.

Results

Density was measured in the laboratory with samples collected from each site. Five samples were cut from each of four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Density measurements were taken for areas of the test images printed with magenta, cyan, green, and blue. Table 4-E.6 shows the results of the density measurements. The amounts listed in the "Density" column are the averages of five measurements taken at each location. The table also presents the standard deviation of these five measurements. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
Solvent-based	LDPE	#S2	5	w	magenta	1.53	0.04	x	magenta	1.55	0.04
					cyan	1.58	0.02		cyan	1.51	0.03
					green	1.39	0.02		green	1.41	0.06
					blue	1.90	0.04		blue	1.97	0.02
				y	magenta	1.45	0.04	z	magenta	1.52	0.03
					cyan	1.46	0.04		cyan	1.50	0.05
					green	1.28	0.02		green	1.36	0.01
					blue	2.04	0.02		blue	2.04	0.03
			7	w	magenta	1.33	0.02	x	magenta	1.31	0.02
					cyan	1.29	0.01		cyan	1.34	0.02
					green	0.86	0.02		green	0.96	0.02
					blue	1.61	0.02		blue	1.68	0.02
				y	magenta	1.32	0.02	z	magenta	1.19	0.02
					cyan	1.22	0.02		cyan	1.22	0.02
					green	1.02	0.02		green	0.74	0.01
					blue	1.69	0.03		blue	1.60	0.02
			L5[b]	w	green	0.70	0.02	x	green	0.75	0.01
				y	not sampled			z	green	0.91	0.02
	PE/EVA	#S2	5	w	magenta	1.51	0.04	x	magenta	1.52	0.04
					cyan	1.46	0.01		cyan	1.61	0.02
					green	1.31	0.02		green	1.35	0.03
					blue	1.87	0.03		blue	1.94	0.07
				y	magenta	1.16	0.04	z	magenta	1.21	0.06
					cyan	1.56	0.02		cyan	1.57	0.03
					green	1.34	0.05		green	1.42	0.04
					blue	1.96	0.09		blue	1.94	0.05

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
Solvent-based	PE/EVA	#S2	7	w	magenta	1.25	0.02	x	not sampled		
					cyan	1.36	0.02				
					green	0.83	0.02				
					blue	1.70	0.01				
				y	not sampled			z	magenta	1.27	0.04
									cyan	1.47	0.02
									green	0.82	0.02
									blue	1.71	0.03
			L7[b]	w	cyan	0.96	0.01	x	cyan	0.98	0.02
					green	0.75	0.02		green	0.78	0.01
				y	not sampled			z	cyan	0.89	0.02
									green	0.82	0.02
	OPP	#S1	9B	w	magenta	1.21	0.01	x	magenta	1.29	0.02
					cyan	1.36	0.03		cyan	1.43	0.03
					green	0.67	0.02		green	0.67	0.01
					blue	1.23	0.02		blue	1.28	0.03
				y	not sampled			z	magenta	1.24	0.02
									cyan	1.52	0.02
									green	0.67	0.02
									blue	1.28	0.05

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
		#S2	10	w	magenta	0.48	0.01	x	magenta	0.50	0.04
					cyan	0.59	0.01		cyan	0.66	0.01
					green	1.16	0.01		green	1.09	0.02
					blue	1.77	0.02		blue	1.76	0.02
				y	magenta	0.48	0.01	z	magenta	0.52	0.02
					cyan	0.64	0.02		cyan	0.70	0.01
					green	1.13	0.04		green	1.15	0.02
					blue	1.72	0.02		blue	1.71	0.01
			L4	w	green	0.60	0.03	x	green	0.70	0.02
				y	not sampled			z	green	0.74	0.01
UV	LDPE	#U2	6	w	magenta	1.61	0.03	x	magenta	1.87	0.03
					cyan	1.36	0.02		cyan	1.28	0.02
					green	1.17	0.01		green	1.18	0.01
					blue	1.87	0.05		blue	1.87	0.03
				y	magenta	1.86	0.05	z	magenta	1.39	0.05
					cyan	1.30	0.03		cyan	1.41	0.03
					green	1.17	0.02		green	1.16	0.01
					blue	1.86	0.04		blue	1.91	0.03
UV	PE/EVA	#U2	6	w	magenta	1.57	0.01	x	magenta	1.60	0.03
					cyan	1.32	0.07		cyan	1.40	0.02
					green	1.26	0.02		green	1.30	0.01
					blue	1.87	0.04		blue	1.73	0.03
				y	magenta	1.63	0.04	z	magenta	1.70	0.03
					cyan	1.37	0.02		cyan	1.44	0.01
					green	1.28	0.01		green	1.28	0.01
					blue	1.78	0.01		blue	1.83	0.04

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
		#U3	8	w	magenta	1.10	0.03	x	magenta	1.22	0.08
					cyan	1.07	0.01		cyan	1.08	0.02
					green	0.92	0.01		green	1.06	0.03
					blue	1.07	0.02		blue	1.16	0.02
				y	not sampled			z	magenta	1.21	0.05
									cyan	1.10	0.02
									green	0.97	0.01
									blue	1.10	0.01
UV (no slip)	LDPE	#U1	11	w	magenta	1.02	0.01	x	magenta	1.07	0.01
					cyan	1.12	0.04		cyan	1.19	0.04
					green	1.44	0.03		green	1.46	0.03
					blue	2.11	0.04		blue	2.20	0.04
				y	magenta	1.13	0.05	z	magenta	1.15	0.10
					cyan	1.26	0.07		cyan	1.42	0.01
					green	1.49	0.04		green	1.59	0.04
					blue	2.18	0.12		blue	2.19	0.03
Water-based	LDPE	#W3	2	w	magenta	1.19	0.02	x	magenta	1.21	0.04
					cyan	1.41	0.02		cyan	1.38	0.01
					green	1.32	0.01		green	1.25	0.03
					blue	2.13	0.04		blue	2.13	0.03
				y	magenta	1.28	0.01	z	magenta	1.24	0.01
					cyan	1.42	0.04		cyan	1.37	0.01
					green	1.22	0.03		green	1.24	0.04
					blue	2.13	0.04		blue	1.98	0.09

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
Water-based	LDPE	#W3	3	w	magenta	1.20	0.02	x	magenta	1.21	0.01
					cyan	0.99	0.03		cyan	1.12	0.04
					green	1.45	0.03		green	1.45	0.03
					blue	2.19	0.04		blue	2.21	0.02
				y	magenta	1.23	0.02	z	magenta	1.29	0.02
					cyan	0.87	0.11		cyan	0.97	0.04
					green	1.46	0.03		green	1.37	0.07
					blue	2.17	0.05		blue	2.15	0.04
			L1	w	green	0.92	0.05	x	green	0.87	0.04
				y	not sampled			z	green	0.96	0.02
	PE/EVA	#W3	2	w	magenta	1.13	0.05	x	magenta	1.10	0.06
					cyan	1.30	0.02		cyan	1.23	0.03
					green	1.39	0.02		green	1.44	0.03
					blue	1.67	0.04		blue	2.18	0.03
				y	magenta	1.10	0.03	z	magenta	1.32	0.04
					cyan	1.30	0.03		cyan	1.04	0.01
					green	1.41	0.01		green	1.39	0.05
					blue	2.14	0.06		blue	2.07	0.04
			3	w	magenta	1.31	0.09	x	magenta	1.21	0.04
					cyan	1.33	0.02		cyan	1.10	0.03
					green	1.55	0.02		green	1.42	0.02
					blue	1.95	0.06		blue	1.89	0.04
				y	magenta	1.24	0.03	z	magenta	1.20	0.01
					cyan	1.12	0.04		cyan	1.17	0.02
					green	1.45	0.01		green	1.38	0.03
					blue	1.94	0.02		blue	1.92	0.03

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
			L6	w	cyan	1.15	0.08	x	cyan	1.08	0.05
					green	0.88	0.02		green	0.86	0.01
				y	not sampled			z	cyan	1.16	0.02
									green	0.93	0.01
Water-based	OPP	#W1	4	w	magenta	1.27	0.01	x	magenta	1.22	0.02
					cyan	1.27	0.01		cyan	1.12	0.01
					green	1.68	0.01		green	1.67	0.02
					blue	1.86	0.02		blue	1.86	0.03
				y	magenta	1.14	0.03	z	magenta	1.31	0.08
					cyan	1.07	0.03		cyan	1.31	0.04
					green	1.66	0.01		green	1.68	0.01
					blue	1.84	0.03		blue	1.55	0.01
		#W2	1	w	magenta	1.34	0.07	x	magenta	1.44	0.03
					cyan	1.40	0.06		cyan	1.43	0.05
					green	1.40	0.02		green	1.32	0.05
					blue	2.29	0.01		blue	2.29	0.01
				y	magenta	1.42	0.03	z	magenta	1.18	0.05
					cyan	1.42	0.04		cyan	1.41	0.03
					green	1.35	0.03		green	1.34	0.03
					blue	2.31	0.03		blue	2.35	0.01
			L3	w	green	0.57	0.02	x	green	0.61	0.01
				y	not sampled			z	green	0.72	0.05

Table 4-E.6 Density Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Density (unitless)	Standard Deviation	Location of Sample[a]	Color	Density (unitless)	Standard Deviation
		#W4	9A	w	magenta	1.32	0.02	x	magenta	1.39	0.03
					cyan	1.53	0.06		cyan	1.51	0.04
					green	1.20	0.02		green	1.25	0.02
					blue	1.66	0.01		blue	1.68	0.01
				y	not sampled			z	magenta	1.42	0.03
									cyan	1.53	0.03
									green	1.25	0.01
									blue	1.70	0.02
			L2	w	green	1.02	0.03	x	green	0.99	0.02
				y	not sampled			z	green	0.98	0.02

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run
[b]"L" indicates data from a laboratory run.

Dimensional Stability

Purpose

The purpose of the dimensional stability test is to measure how the substrate responds structurally during printing. The dimensional stability test is based on methods developed by Western Michigan University.

Equipment

Accurate 10 inch x 10 inch template for cutting sample sheets
Steel measuring scale graduated in divisions of 0.01 inches and at least 12 inches in height
Controlled temperature and humidity in a room or convection oven

Procedure

1. Using the 10 inch x 10 inch template, cut three samples from the test web: one from each edge and one from the center. On very wide webs, more than three locations may be advisable.

2. Mark each sample with the location and directional information before cutting it from the original web or sheet to avoid any possibility of error in subsequent identification.

3. The standard test reference is A.S.T.M. designation D-1204.

4. Record the results in thousandths of an inch (0.001 inch) per the standard test reference.

Results

Dimensional stability for width and length was measured on samples cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Green and blue printed samples were tested for dimensional stability. Samples from the left and right sides of the web were tested for each color also. Table 4-E.7 presents the complete data from each of the performance demonstration sites.

Table 4-E.7 Dimensional Stability for Performance Demonstrations

Ink System	Film	Product Line	Site	Location of Sample[a]	Width (mm)				Length (mm)			
					Left Blue	Left Green	Right Blue	Right Green	Left Blue	Left Green	Right Blue	Right Green
Original plate dimensions					57.84	56.83	51.50	50.90	77.80	76.15	75.44	75.32
Solvent-based	LDPE	#S2	5	w	57.70	56.19	50.95	51.01	79.53	77.49	77.44	76.83
				x	57.92	56.75	51.35	51.02	79.58	77.45	77.12	77.19
				y	58.13	56.90	51.16	51.29	79.34	77.24	77.21	76.57
				z	58.56	56.95	51.31	51.04	79.41	76.98	77.10	77.11
			7	w	58.18	57.14	51.12	51.12	77.82	76.18	76.25	76.11
				x	58.00	56.71	51.32	51.32	78.23	75.95	75.69	75.70
				y	58.42	57.12	51.26	51.53	77.21	75.95	75.70	75.38
				z	58.22	57.14	51.25	51.13	77.83	75.94	75.87	75.78
	PE/EVA	#S2	5	w	58.02	56.43	51.11	51.24	79.98	77.74	77.75	77.51
				x	57.89	56.77	51.56	51.27	79.68	77.64	77.72	76.95
				y	57.04	56.89	50.91	51.34	79.83	77.88	77.10	76.70
				z	58.30	56.72	51.26	51.33	80.05	77.62	77.35	77.17
			7	w	57.94	56.92	50.89	50.51	78.71	76.69	76.76	76.52
				z	57.77	56.42	51.06	51.05	79.38	77.14	77.10	77.00
	OPP	#S1	9B	w	57.44	56.08	51.25	50.92	78.83	76.32	76.62	76.35
				x	57.50	55.95	51.13	50.60	79.07	76.49	76.62	76.66
				z	57.77	56.32	51.04	50.67	78.59	76.22	76.55	76.22
		#S2	10	w	57.46	56.40	50.73	50.99	79.05	77.04	77.50	77.42
				x	57.86	56.77	51.06	50.61	80.35	77.67	77.80	77.25
				y	57.96	56.07	51.14	51.01	80.04	77.82	77.99	77.54
				z	57.68	56.52	50.79	51.05	79.35	77.23	77.59	77.47

Table 4-E.7 Dimensional Stability for Performance Demonstrations (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Width (mm)				Length (mm)			
					Left Blue	Left Green	Right Blue	Right Green	Left Blue	Left Green	Right Blue	Right Green
UV	LDPE	#U2	6	w	58.61	57.09	51.48	50.98	78.48	75.36	76.43	75.42
				x	58.09	56.83	51.08	50.72	79.05	77.05	76.81	76.38
				y	58.05	56.74	51.37	50.98	79.17	76.72	77.07	76.81
				z	58.30	56.89	51.26	50.90	79.47	77.91	77.40	76.25
	PE/EVA	#U2	6	w	57.91	56.68	51.19	51.05	80.28	77.67	77.19	77.61
				x	57.79	57.04	51.22	51.23	79.75	77.00	77.01	76.93
				y	57.75	56.54	51.07	50.80	80.07	77.43	77.30	76.33
				z	57.79	57.07	51.43	51.33	79.97	77.35	77.64	77.16
UV	PE/EVA	#U3	8	w	57.41	56.80	50.86	50.91	77.57	75.05	75.36	75.28
				x	57.43	56.55	51.14	51.01	77.50	75.40	75.39	75.45
				z	57.67	56.94	50.97	51.22	77.31	75.47	74.99	75.23
UV (no slip)	LDPE	#U1	11	w	57.83	56.82	51.18	51.02	79.52	77.23	77.24	76.73
				x	58.15	56.71	51.04	50.84	79.49	77.01	77.98	77.05
				y	58.03	57.00	51.37	50.92	79.28	77.38	77.41	76.71
				z	57.77	56.89	51.35	51.01	79.90	77.63	77.86	77.36
Water-based	LDPE	#W3	2	w	58.09	56.76	51.54	51.72	78.32	75.99	76.47	76.34
				x	57.00	56.12	51.25	51.17	78.76	76.17	76.60	76.44
				y	57.92	56.82	51.17	51.01	78.21	76.06	76.77	76.56
				z	58.02	56.81	51.33	51.18	78.32	76.04	76.42	76.35
			3	w	57.96	57.22	51.35	50.98	78.29	75.87	76.68	76.78
				x	57.76	56.37	51.18	50.97	78.25	76.69	76.13	75.96
				y	57.93	56.90	50.97	50.80	78.54	76.38	76.33	75.90
				z	58.26	56.95	51.35	51.18	78.91	76.35	76.58	75.93

Table 4-E.7 Dimensional Stability for Performance Demonstrations (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Width (mm)				Length (mm)			
					Left Blue	Left Green	Right Blue	Right Green	Left Blue	Left Green	Right Blue	Right Green
	PE/EVA	#W3	2	w	57.64	57.02	51.09	51.16	79.76	77.39	76.40	77.09
				x	58.15	57.03	51.42	51.35	80.00	77.25	77.64	77.41
				y	58.36	57.46	51.61	51.19	80.14	77.51	77.58	76.84
				z	58.23	56.95	51.45	51.36	79.62	77.51	76.96	77.33
			3	w	58.18	56.47	51.10	51.02	78.90	76.61	76.54	76.91
				x	57.78	56.74	51.28	51.02	78.91	77.15	76.82	76.37
				y	58.15	56.78	51.05	51.41	78.60	77.16	76.82	76.26
				z	57.95	57.00	51.07	51.23	78.76	76.80	77.07	76.99
	OPP	#W1	4	w	57.96	56.81	50.69	50.91	79.26	76.82	76.69	76.96
				x	58.06	56.12	50.51	50.98	79.34	77.06	76.45	76.45
				y	57.89	56.85	51.18	50.83	79.23	76.87	76.67	76.33
				z	57.86	56.70	51.04	50.92	79.79	76.80	76.76	76.13
		#W2	1	w	57.75	56.85	51.12	50.16	78.69	77.49	76.88	77.08
				x	57.97	55.82	50.09	51.31	79.09	76.67	76.88	74.89
				y	57.97	56.96	50.89	50.97	79.00	76.97	77.09	76.63
				z	57.84	56.96	51.33	50.37	79.51	76.91	77.12	76.56
Water-based	OPP	#W4	9A	w	57.92	56.32	51.18	51.11	78.87	76.57	77.07	77.17
				x	57.74	56.63	50.54	50.63	79.39	77.45	76.66	76.52
				z	57.81	56.48	50.83	51.33	78.91	76.63	76.20	76.16

[a]Samples were taken at three locations from the printed sample:
w = beginning of the run
x = thirty minutes into the run
y = sixty minutes into the run
z = end of the run

Gloss

Purpose

The purpose of the gloss test is to evaluate the light that is reflected off the ink surface when a light is shined at that surface from an angle. The gloss test is based on methods developed by Western Michigan University.

Equipment

Gardner Micrometer (60° angle)

Procedure

1. Light energy is applied to a surface through a special aperture and reflected back through a photocell. The reflected light is converted into electrical energy to drive a meter reading from 0 to 100 (the greater the reflective light, the greater the meter reading). For this experiment, the Gardner Micrometer will be used.

2. Follow the manufacturer's recommended procedure for calibration to the standard tiles. Clean the tile standards before calibration to increase accuracy. Place the glossmeter port over the center of the black tile (note that the direction of the arrows should align). Verify the instrument while holding the meter in position and adjusting the control knob to the indicated number on the black standard. Do the same with the white tile using the white standard calibration number.

3. Take measurements of five samples from four locations of the run. The selected area for the readings should be consistent in ink coverage or solid ink densities. On LDPE, the gloss was measured for magenta, cyan, blue, and green over a white ink background, and also for white, green, and blue on clear film. On PE/EVA, the gloss was measured for magenta, cyan, blue, and green on white film.

4. Place the glossmeter over the sample area (at least 3 readings on a 3 inch x 6 inch area) and press the operate button. For each sample there will be 10 readings, 5 each side across the sheet. Repeat the readings for all five colors.

Results

Gloss was measured in the laboratory with samples collected from each site. Five readings are taken from each of four locations on the run, and the average of these readings is what is recorded for each location. Samples were cut for four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

For LDPE, magenta, cyan, green, and blue samples were tested on a white ink background; white, green, and blue samples were tested on clear LDPE film. Magenta, cyan, green, and blue samples were also tested on a white PE/EVA substrate. Table 4-E.8 presents the complete data from each of the performance demonstration sites and laboratory runs. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.8 Gloss for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Color[a]	Location of Sample[b]	Gloss	Location of Sample	Gloss	Location of Sample	Gloss	Location of Sample[b]	Gloss
Solvent-based	LDPE	#S2	5	magenta	w	42.5	x	53.5	y	54.2	z	50.1
				cyan		44.4		43.7		58.0		52.3
				green		47.5		49.3		57.8		45.8
				blue		52.4		46.5		56.9		50.5
				white on clear		20.0		42.7		41.7		38.5
				green on clear		43.5		35.9		50.2		39.4
				blue on clear		41.2		33.4		45.0		42.9
			7	magenta	w	53.9	x	51.3	y	45.1	z	56.1
				cyan		45.3		45.2		39.5		53.6
				green		51.0		50.3		53.2		64.0
				blue		51.9		52.0		49.8		49.5
				white on clear		42.4		58.2		57.7		60.1
				green on clear		62.5		73.2		56.7		67.2
				blue on clear		67.5		69.6		61.6		54.3
			L5[c]	green	w	37.5	x	37.2	y	not sampled	z	31.2
				white on clear		39.6		39.4				34.2
				green on clear		34.5		35.6				29.0
	PE/EVA	#S2	5	magenta	w	62.1	x	75.0	y	62.8	z	63.7
				cyan		58.1		62.9		55.1		52.2
				green		59.2		60.6		56.0		45.7
				blue		60.4		49.1		51.6		49.8
			7	magenta	w	56.5	x	not sampled	y	not sampled	z	63.3
				cyan		61.4						63.7
				green		72.9						75.8
				blue		42.8						57.2
			L7	cyan	w	39.6	x	39.4	y	not sampled	z	38.2
				green		35.6		35.9				31.8

Table 4-E.8 Gloss for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Color[a]	Location of Sample[b]	Gloss	Location of Sample	Gloss	Location of Sample	Gloss	Location of Sample[b]	Gloss
UV	LDPE	#U2	6	magenta	w	29.2	x	27.3	y	26.6	z	30.6
				cyan		37.6		50.9		52.6		51.8
				green		43.2		46.8		39.0		49.4
				blue		48.6		37.9		29.1		44.0
				white on clear		40.9		44.3		50.3		59.7
				green on clear		55.3		63.9		61.9		50.5
				blue on clear		50.0		67.0		58.9		64.0
	PE/EVA	#U2	6	magenta	w	36.4	x	27.8	y	28.3	z	30.1
				cyan		44.1		47.5		45.3		61.0
				green		52.8		49.7		51.6		49.0
				blue		65.5		61.1		52.3		54.4
		#U3	8	magenta	w	44.1	x	37.1	y	not	z	37.3
				cyan		55.2		38.0		sampled		49.3
				green		28.4		22.3				22.6
				blue		30.2		33.0				33.2
UV (no slip)	LDPE	#U1	11	magenta	w	29.7	x	46.0	y	34.2	z	37.3
				cyan		27.9		24.1		21.8		22.9
				green		21.6		24.3		22.2		30.4
				blue		24.1		35.4		26.3		48.4
				white on clear		35.6		37.2		36.6		38.6
				green on clear		41.8		41.9		41.1		43.7
				blue on clear		29.2		24.6		22.4		35.5
Water-based	LDPE	#W3	2	magenta	w	38.9	x	43.9	y	31.3	z	28.7
				cyan		39.5		40.1		42.8		32.2
				green		47.9		49.3		29.0		33.6
				blue		47.9		47.0		30.4		34.5
				white on clear		46.0		44.8		47.5		50.1
				green on clear		61.1		47.5		57.9		59.0
				blue on clear		34.9		42.4		52.3		58.7

Table 4-E.8 Gloss for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Color[a]	Location of Sample[b]	Gloss	Location of Sample	Gloss	Location of Sample	Gloss	Location of Sample[b]	Gloss
Water-based	LDPE	#W3	3	magenta	w	29.5	x	48.7	y	47.3	z	32.1
				cyan		47.0		37.6		40.7		33.4
				green		36.8		35.3		31.1		25.0
				blue		34.8		31.1		23.7		19.9
				white on clear		42.7		51.1		45.1		42.0
				green on clear		39.0		61.6		61.0		56.0
				blue on clear		56.4		56.4		41.8		36.1
			L1	green	w	21.3	x	22.9	y	not sampled	z	22.3
				white on clear		41.4		27.7				30.6
				green on clear		40.4		49.6				42.6
	PE/EVA	#W3	2	magenta	w	61.4	x	55.0	y	43.6	z	47.6
				cyan		53.1		49.2		39.0		42.8
				green		60.5		61.7		57.1		53.1
				blue		55.7		56.1		46.2		41.0
			3	magenta	w	59.9	x	62.3	y	49.7	z	73.9
				cyan		57.6		57.8		50.0		42.2
				green		45.7		57.6		54.9		62.7
				blue		53.8		56.0		54.8		69.0
			L6	green	w	32.7	x	56.7	y	not sampled	z	32.7
				blue		56.2		45.1				39.4

[a]For LDPE, magenta, cyan, green, and blue were tested on a white ink background. White, green, and blue were also tested on a clear LDPE film, and are denoted in the table as "white on clear," "green on clear," and "blue on clear." Magenta, cyan, green, and blue were tested on a white PE/EVA film.
[b]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run
[c]"L" indicates data from a laboratory run.

Heat Resistance/Heat Seal

Purpose

The purpose of this test was to determine the heat resistance of the printed product. Heat resistance is the degree to which a printed substrate will resist transfer to itself or to an unprinted surface when heated. The heat resistance/heat seal test is based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

A Sentinel Heat Sealer was used to measure heat resistance.

Procedure

1. Preheat the jaws of the heat sealer until the desired temperature is obtained. Record the temperature.

2. Set the desired pressure and dwell time. Record.

3. Sandwich the sample between aluminum foil or paper and place the sample between the jaws of the heat sealer.

4. Depress the foot pedal to activate machine.

5. When dwell time is completed, remove the samples and allow them to cool.

6. Test the heat seal.

Results

This test was accomplished by checking for ink transfer upon peeling apart the heated samples. Results are recorded as "pass" (no ink transfer), or "fail" (transfer of ink). In the case of a failure, the percent of ink transferred is evaluated and recorded. Samples were tested for both printed substrate to unprinted substrate and printed substrate to printed substrate.

Heat resistance was measured in the laboratory with samples collected from the four sites (Sites 1, 4, 9, and 10) which laminated the printed OPP substrate. Samples were cut from up to four locations during the run as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

The images used in the heat resistance/heat seal tests had areas printed with blue, green, and white ink. Table 4-E.9 shows the heat resistance test results for each site. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.9 Heat Resistance/Heat Seal Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Ink-Un[b] Pass/ Fail	Ink-Un Result	Ink-Ink[c] Pass/ Fail	Ink-Ink Result
Solvent-based	OPP	#S1	9B	w	blue	P		F	10%
					green	P		P	
					white	F	10%	F	10%
				x	blue	F	10%	F	10%
					green	P		P	
					white	F	10%	F	10%
				z	blue	P		P	
					green	P		P	
					white	F	20%	F	20%
		#S2	10	w	blue	F	40%	F	50%
					green	F	40%	F	50%
					white	F	30%	F	50%
				x	blue	F	30%	F	40%
					green	F	40%	F	40%
					white	F	40%	F	30%
				z	blue	F	30%	F	40%
					green	F	40%	F	40%
					white	F	40%	F	30%
			L4[d]	w	green	P		P	
					white	P		P	
				x	green	P		P	
					white	P		P	
				z	green	P		P	
					white	P		P	
Water-based	OPP	#W1	4	w	blue	P		F	20%
					green	P		F	20%
					white	F	10%	F	20%
				x	blue	P		F	20%
					green	P		F	20%
					white	F	10%	F	40%
				y	blue	P		F	20%
					green	P		F	20%
					white	F	10%	F	20%
				z	blue	P		F	20%
					green	P		F	20%
					white	F	20%	F	30%

Table 4-E.9 Heat Resistance/Heat Seal Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Ink-Un[b] Pass/ Fail	Ink-Un Result	Ink-Ink[c] Pass/ Fail	Ink-Ink Result
		#W2	1	w	blue	F	20%	F	20%
					green	F	20%	F	30%
					white	F	10%	F	50%
				x	blue	F	10%	F	20%
					green	F	20%	F	40%
					white	F	10%	F	50%
				y	blue	F	20%	F	20%
					green	F	20%	F	50%
					white	F	10%	F	50%
				z	blue	F	20%	F	20%
					green	F	20%	F	20%
					white	F	20%	F	60%
			L3	w	green	F	10%	P	
					white	F	10%	F	10%
				x	green	F	10%	F	10%
					white	F	10%	F	10%
				z	green	F	10%	F	10%
					white	F	10%	F	10%
		#W4	9A	w	blue	F	5%	F	10%
					green	F	5%	F	10%
					white	P		P	
				x	blue	F	10%	F	10%
					green	F	10%	F	10%
					white	P		P	
				z	blue	F	10%	F	10%
					green	F	10%	F	10%
					white	P		P	
			L2	w	green	F	10%	F	20%
					white	F	10%	F	20%
				x	green	F	30%	F	20%
					white	F	30%	F	20%
				z	green	F	10%	F	40%
					white	F	10%	F	40%

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]"Ink-Un" represents ink transferred from a printed substrate to an unprinted substrate.

[c]"Ink-Ink" represents ink transferred from a printed substrate to a printed substrate.

[d]"L" indicates data from a laboratory run.

Ice Water Crinkle Adhesion

Purpose

The purpose of the ice water crinkle adhesion test is to evaluate the integrity and flexibility of the ink on the substrate when exposed to refrigerator and freezer conditions. This test measures a combination of the ink's adhesive and flexibility properties. The ice water crinkle adhesion test is based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

Rollout of ink on appropriate substrate
Four-ounce jar
Ice water
Freezer

Procedure

1. Roll out the standard and batch side by side.

2. Submerge the split roll-out into ice water for thirty minutes.

3. Remove the print.

4. While the print is still wet, firmly grasp the print between the thumb and forefinger of each hand with about one inch of print between the two thumbs.

5. Bring the hands together and rub in opposite directions fairly rapidly ten times. One complete cycle consists of both a back and forward motion of the wrists.

6. Inspect the proof for ink removal.

Results

The ice water crinkle adhesion test was measured in the laboratory with samples collected from each site. Sites 1, 4, 9, and 10 were not tested in the laboratory because the OPP substrate printed at these sites were laminated to another substrate. Samples for testing were cut from four locations during the run as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Due to the aborted run using the PE/EVA substrate at Site 7, samples were only taken from the beginning (w) and the end (z) of the run for testing in the laboratory. Site 8 also had a shorter run for the PE/EVA substrate, so samples were only taken from the beginning (w), thirty minutes into run (x), and the end of the run (z). The laboratory runs conducted at Western Michigan were shorter in duration than the demonstration runs, so samples for testing were only cut from three locations (w, x, and z).

Table 4-E.10 presents the data from all of the performance demonstration sites and laboratory runs. When a site number begins with an "L," the data were taken from a run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.10 Ice Water Crinkle Adhesion Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Any Ink Removal?
Solvent-based	LDPE	#S2	5	w	no
				x	no
				y	no
				z	no
			7	w	no
				x	no
				y	no
				z	no
			L5[b]	w	no
				x	no
				z	no
	PE/EVA	#S2	5	w	no
				x	no
				y	no
				z	no
			7	w	no
				z	no
			L7	w	no
				x	no
				z	no
UV	LDPE	#U2	6	w	yes, less than 15%
				x	yes, less than 15%
				y	yes, less than 15%
				z	yes, less than 15%
	PE/EVA	#U2	6	w	yes, less than 15%
				x	yes, less than 15%
				y	yes, less than 15%
				z	yes, less than 15%
		#U3	8	w	no
				x	no
				y = z	no
UV (no slip)	LDPE	#U1	11	w	no
				x	no
				y	no
				z	no

Table 4-E.10 Ice Water Crinkle Adhesion Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Any Ink Removal?
Water-based	LDPE	#W3	2	w	no
				x	no
				y	no
				z	no
			3	w	yes, less than 5%
				x	yes, less than 5%
				y	yes, less than 5%
				z	yes, less than 5%
			L1	w	no
				x	no
				z	no
	PE/EVA	#W3	2	w	no
				x	no
				y	no
				z	no
			3	w	no
				x	yes, less than 5%
				y	no
				z	no
			L6	w	yes, about 30% of the green ink and less than 15% of the blue ink
				x	yes, about 30% of the green ink and less than 15% of the blue ink
				z	yes, about 30% of the green ink and less than 15% of the blue ink

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]"L" indicates data from a laboratory run.

Image Analysis

Purpose

The purpose of the image analysis test is to measure how well the image is formed as it appears under magnification. The image analysis test is based on methods developed by Western Michigan University.

Equipment

High resolution optics
RGB digital frame grabber
Computer with Image ProPlus Analysis software

Procedure

1. Using the equipment listed above, quantify the following dot characteristics:
    - maximum and minimum dot area
    - maximum and minimum perimeter

2. Take readings from five random places of each sample color. A minimum of 50 dots per sample must be measured. Record the average and standard deviation.

Results

Image analysis was measured in the laboratory with samples collected from each site. Samples were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Since the purpose of this test was to evaluate screened dot detail as used in process color reproduction, only the magenta and cyan process inks were analyzed. Table 4-E.11 shows the results of the image analysis measurements. The results for dot area and perimeter are the averages of two scans; each scan measured 50 dots. The standard deviation is also shown in Table 4-E.11. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
Solvent-based	LDPE	#S2	5	w	magenta	978.40	67.75	120.20	6.50
					cyan	710.55	65.90	103.25	5.25
				x	magenta	975.60	70.95	131.30	7.75
					cyan	697.35	46.60	101.95	4.05
				y	magenta	948.75	75.75	132.60	6.95
					cyan	730.90	61.10	104.80	4.35
				z	magenta	910.35	70.35	116.15	5.40
					cyan	764.65	56.85	107.05	4.50
			#7	w	magenta	1296.40	94.05	145.30	7.85
					cyan	776.40	54.95	113.10	5.95
				x	magenta	902.40	74.95	123.60	9.65
					cyan	423.00	66.00	102.50	13.30
				y	magenta	1024.15	79.00	129.95	8.35
					cyan	463.85	70.25	111.80	9.90
				z	magenta	975.90	69.80	123.70	6.20
					cyan	564.55	60.15	101.75	12.25
	PE/EVA	#S2	5	w	magenta	1365.65	79.90	146.60	8.00
					cyan	689.55	46.95	99.20	3.65
				x	magenta	902.45	71.45	120.75	6.35
					cyan	825.50	57.60	112.40	4.85
				y	magenta	596.60	66.25	97.30	6.50
					cyan	653.85	52.75	101.60	4.25
				z	magenta	784.00	65.80	110.60	5.65
					cyan	715.10	69.05	105.60	6.50
			7	w	magenta	419.10	55.05	112.00	15.95
					cyan	273.45	85.40	90.30	21.05
				x	magenta	1088.50	107.90	134.25	17.20
					cyan	374.30	63.50	116.85	18.75

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
Solvent-based	OPP	#S1	9B	w	magenta	504.85	31.40	89.50	5.65
					cyan	463.90	32.00	80.00	3.40
				x	magenta	664.20	52.75	104.30	8.75
					cyan	569.05	34.70	89.40	3.45
				z	magenta	692.70	45.25	114.00	7.60
					cyan	466.30	36.25	83.20	4.30
		#S2	10	w	magenta	342.80	126.65	106.10	31.45
					cyan	753.75	118.55	131.55	16.20
				x	magenta	580.95	129.95	128.35	24.65
					cyan	937.05	113.05	131.50	21.25
				y	magenta	671.10	84.40	130.30	14.25
					cyan	1093.25	115.05	148.50	25.95
				z	magenta	678.80	82.55	124.80	17.30
					cyan	1087.85	120.10	644.05	27.45
UV	LDPE	#U2	6	w	magenta	730.90	68.95	116.75	8.10
					cyan	937.95	55.65	120.10	5.85
				x	magenta	748.65	75.10	121.10	5.85
					cyan	1069.40	63.75	130.00	4.90
				y	magenta	779.85	80.30	121.80	7.90
					cyan	983.65	77.70	129.05	9.95
				z	magenta	605.70	47.80	92.55	4.30
					cyan	876.91	155.45	159.40	22.80

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
	PE/EVA	#U2	6	w	magenta	651.10	65.00	103.25	6.05
					cyan	1365.05	80.50	147.05	5.60
				x	magenta	643.80	55.10	97.25	4.95
					cyan	1177.05	67.45	142.20	9.30
				y	magenta	679.30	60.00	99.50	5.30
					cyan	557.05	71.40	132.40	7.30
				z	magenta	715.30	59.80	104.50	5.10
					cyan	469.75	75.45	133.50	17.25
UV	PE/EVA	#U3	8	w	magenta	463.75	43.00	81.50	8.30
					cyan	307.35	38.65	84.30	5.05
				x	magenta	463.45	50.45	100.35	9.30
					cyan	410.70	27.75	78.20	3.45
				z	magenta	513.65	53.05	93.50	9.55
					cyan	436.30	32.15	79.30	4.55
UV (no slip)	LDPE	#U1	11	w	magenta	374.74	42.46	73.92	4.10
					cyan	507.24	31.40	86.52	3.17
				x	magenta	481.49	50.30	82.62	4.57
					cyan	611.68	53.09	95.98	4.83
				y	magenta	487.06	50.59	83.52	4.82
					cyan	555.78	31.01	91.52	2.98
				z	magenta	482.81	53.27	83.16	5.16
					cyan	611.93	55.35	98.31	4.71

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
Water-based	LDPE	#W3	2	w	magenta	577.95	67.70	93.35	5.80
					cyan	942.85	66.25	119.90	4.70
				x	magenta	550.30	54.20	88.15	5.75
					cyan	986.60	51.40	122.90	4.65
				y	magenta	651.10	57.25	95.85	4.85
					cyan	1019.85	77.45	131.55	6.85
				z	magenta	654.75	72.40	95.85	5.40
					cyan	751.39	68.05	109.10	6.15
			3	w	magenta	1093.00	114.60	148.90	9.10
					cyan	578.55	47.65	95.65	4.15
				x	magenta	888.00	119.15	133.05	10.35
					cyan	560.70	33.90	89.90	3.20
				y	magenta	737.30	56.50	106.70	5.30
					cyan	716.35	46.40	105.75	4.70
				z	magenta	832.75	74.05	120.55	9.30
					cyan	579.25	40.75	97.35	5.30

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
Water-based	PE/EVA	#W3	2	w	magenta	551.35	68.40	92.30	7.60
					cyan	1022.00	32.55	127.35	7.95
				x	magenta	846.70	88.55	113.65	9.00
					cyan	909.40	103.35	115.25	7.10
				y	magenta	554.05	37.25	96.40	6.45
					cyan	950.95	72.60	116.90	5.30
				z	magenta	871.20	93.55	126.10	11.05
					cyan	761.85	99.60	115.00	10.70
			3	w	magenta	690.00	58.80	100.90	6.20
					cyan	891.65	67.25	117.25	6.85
				x	magenta	824.20	58.10	107.95	4.60
					cyan	984.35	51.40	126.15	8.75
				y	magenta	613.45	47.20	94.05	4.05
					cyan	776.05	54.65	109.10	3.90
				z	magenta	471.40	37.65	84.80	6.55
					cyan	709.30	36.75	104.25	5.05
	OPP	#W1	4	w	magenta	830.25	47.45	121.05	8.10
					cyan	829.35	54.70	114.45	6.50
				x	magenta	829.65	61.60	117.20	5.90
					cyan	700.10	44.60	107.90	5.45
				y	magenta	850.90	45.50	113.65	5.20
					cyan	758.65	34.35	110.60	5.35
				z	magenta	840.70	49.90	114.20	5.35
					cyan	836.75	44.15	115.15	5.55

Table 4-E.11 Image Analysis Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Dot Area (micron^2)	Standard Deviation - Area	Dot Perimeter (microns)	Standard Deviation - Perimeter
		#W2	1	w	magenta	450.70	69.85	110.75	18.50
					cyan	397.94	28.70	81.55	4.25
				x	magenta	361.65	79.80	111.45	13.50
					cyan	354.55	29.90	85.35	4.85
				y	magenta	347.10	56.10	84.15	16.25
					cyan	292.60	31.45	78.30	7.85
				z	magenta	326.90	39.35	84.15	16.25
					cyan	309.75	35.40	81.23	12.05
Water-based	OPP	#W4	9A	w	magenta	701.65	42.90	101.40	3.90
					cyan	535.65	106.45	90.55	12.25
				x	magenta	716.85	47.35	111.45	4.45
					cyan	861.10	100.10	82.70	14.00
				z	magenta	728.26	41.40	112.90	8.80
					cyan	849.65	110.55	114.15	8.35

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

Jar Odor

Purpose

The purpose of this test is to evaluate the type and strength of the odor produced by the ink film on the substrate. The jar odor test is based on methods developed by Western Michigan University.

Equipment

Glass jars (eight ounces) with screw caps having foil liners.
Oven

Procedure

1. Clean the jars and dry them in an oven.

2. Collect samples from the interior of the rolls.

3. Place the printed sample in a jar and seal the jar with the screw cap.

4. Place the jar in the oven at 100°F for two hours.

5. Repeat the procedure for a sample of unprinted substrate as the test control.

6. Open the jar and sniff immediately. Record qualitative assessment of odor.

Results

The jar odor test was measured in the laboratory with samples collected from each site. Samples for testing were cut from two locations as indicated by the following symbols:

c = unprinted area (control)
x = printed area

Results are presented in Chapter 4.

Mottle/Lay

Purpose

The purpose of this test was to evaluate the mottle of the printed substrate. Mottle is the non-uniformity in appearance, or variation in density, of an ink film layer. The mottle/lay test is based on methods developed by Western Michigan University.

Equipment

The Tobias Associates Model MTI Mottle Tester is used to measure mottle. The MTI Model is made up of four main component: a probe or measurement head, a rotating drum that carries the sample, a microprocessor that performs all control and analysis functions, and a video display monitor.

Procedure

1. Calibrate the Mottle Tester before use. Calibrate by placing the calibration standard on the scanning drum with the "center line" marks aligned with the "scan start" mark. Follow the instructions through the main menu of computer. There are two standards for calibration: a white area for setting the ZERO (high reflectivity) and a black area for setting CAL (gain adjustment).

2. For testing, use samples of all substrates (LDPE, PE/EVA, OPP) with two samples from each of the front, middle, and end of the runs. Perform testing on all five colors. Use approximate sample widths of 38 mm (2 inches) with a scannable length of 100 mm (4 inches). This will produce 500 data points, 0.2 mm per point. The scannable length is the length of the sample that is free from any marks or obstructions. Samples must be cut from solid (100% coverage) area.

3. Samples should be mounted to the drum with masking tape, making sure that the tape is out of the scanning area.

4. Set the scan parameters and then select operating functions from the main menu. Follow the instructions manual for an explanation of menu options.

Results

This test was accomplished by using a Mottle Tester (a device specifically designed for this test) to measure the difference in reflective density of a printed sample. For this test, a twelve inch square sample was attached to the Mottle Tester and scanned. Multiple density measurement points (250 - 500) were collected during twenty linear scans over the sample area. The result is a Mottle Index which is derived from these measurement points.

Mottle was measured in the laboratory with samples collected from each site. Samples were cut from three locations during the run as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
z = end of run

The test image had areas printed with green and blue which were used to test for mottle. Table 4-E.12 shows the Mottle Index and standard deviation for these two ink colors from each site. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.12 Mottle Index for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Mottle Index	Standard Deviation
Solvent-based	LDPE	#S2	5	w	green	59.0	3.5
					blue	302.5	46.5
				x	green	93.5	17.0
					blue	286.5	36.0
				z	green	64.5	7.0
					blue	875.0	535.5
			7	w	green	45.5	4.0
					blue	216.5	18.5
				x	green	46.0	6.5
					blue	311.0	26.0
				z	green	34.5	3.5
					blue	258.5	28.5
Solvent-based	LDPE	#S2	L5[b]	w	green	219.5	9.0
				x	green	193.0	15.0
				z	green	262.0	62.0
	PE/EVA	#S2	5	w	green	71.5	5.5
					blue	288.5	25.5
				x	green	87.5	28.0
					blue	276.5	49.0
				z	green	74.0	9.5
					blue	306.0	30.5
			7	w	green	89.5	4.0
					blue	410.0	63.0
				z	green	45.5	3.5
					blue	349.0	27.0
			L7	w	green	362.5	26.0
				x	green	357.5	31.9
				z	green	349.4	21.7

Table 4-E.12 Mottle Index for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Mottle Index	Standard Deviation
	OPP	#S1	9B	w	green	43.0	4.0
					blue	257.0	20.5
				x	green	44.5	6.0
					blue	353.0	35.5
				z	green	43.5	5.0
					blue	408.5	37.5
		#S2	10	w	green	79.5	4.5
					blue	380.5	27.0
				x	green	111.5	7.5
					blue	420.5	33.0
				z	green	97.5	7.5
					blue	401.5	32.0
			L4	w	green	107.5	10.0
				x	green	137.5	13.0
				z	green	116.5	11.0
UV	LDPE	#U2	6	w	green	87.5	7.0
					blue	320.5	24.0
				x	green	73.0	5.5
					blue	281.0	28.0
				z	green	58.5	3.5
					blue	251.5	30.5
	PE/EVA	#U2	6	w	green	62.5	11.0
					blue	312.5	57.0
				x	green	56.5	3.0
					blue	474.0	93.5
				z	green	57.0	4.0
					blue	424.5	101.5
UV	PE/EVA	#U3	8	w	green	48.0	3.5
					blue	379.0	29.0
				x	green	50.5	6.0
					blue	508.0	57.5
				z	green	53.0	6.0
					blue	599.5	74.0
UV (no slip)	LDPE	#U1	11	w	green	68.5	5.5
					blue	629.0	106.0
				x	green	47.0	5.0
					blue	382.5	43.0
				z	green	51.0	5.0
					blue	446.0	50.0

Table 4-E.12 Mottle Index for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Mottle Index	Standard Deviation
Water-based	LDPE	#W3	2	w	green	122.0	7.5
					blue	1144.0	84.5
				x	green	114.5	6.5
					blue	999.0	50.5
				z	green	155.0	11.0
					blue	763.0	42.5
			3	w	green	82.0	9.5
					blue	491.5	34.0
				x	green	87.5	5.5
					blue	588.5	50.5
				z	green	79.0	7.5
					blue	605.5	49.0
			L1	w	green	389.0	27.0
				x	green	399.0	26.0
				z	green	379.0	28.0
	PE/EVA	#W3	2	w	green	90.0	5.0
					blue	1324.0	89.5
				x	green	75.0	6.5
					blue	658.5	74.5
				z	green	107.5	9.0
					blue	1116.5	99.0
			3	w	green	87.0	5.5
					blue	793.5	45.5
				x	green	95.0	6.0
					blue	966.0	57.7
				z	green	95.5	5.5
					blue	838.5	71.5

Table 4-E.12 Mottle Index for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Color	Mottle Index	Standard Deviation
Water-based	PE/EVA	#W3	L6	w	green	227.0	14.0
				x	green	203.0	12.0
				z	green	88.0	8.0
	OPP	#W1	4	w	green	206.0	27.0
					blue	1063.0	98.0
				x	green	193.0	50.0
					blue	1004.5	156.5
				z	green	116.0	8.5
					blue	967.5	134.5
		#W2	1	w	green	44.5	3.5
					blue	219.5	48.0
				x	green	54.5	3.0
					blue	402.5	61.5
				z	green	50.5	4.0
					blue	343.0	40.5
			L3	w	green	169.0	9.5
				x	green	131.0	19.5
				z	green	262.0	62.0
		#W4	9A	w	green	38.0	3.0
					blue	174.5	17.0
				x	green	40.5	7.5
					blue	187.5	19.5
				z	green	36.5	3.5
					blue	212.5	15.5
			L2	w	green	99.0	15.5
				x	green	128.5	10.5
				z	green	251.5	22.0

[a]Samples were taken at three locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
z = end of the run
[b]"L" indicates data from a laboratory run.

Opacity

Purpose

The purpose of this test is to measure the opacity of an ink film. Opacity is the degree to which light can pass through an object. It is expressed as the percentage of light transmitted through both the ink film and substrate. The opacity test is based on methods developed by Western Michigan University.

Equipment

Datacolor Spectraflash 600
Diano-BLN opacity meter

Procedure

1. Adjust the standard and batch reflectance by magnesium oxide factors, and then calculate the A/2 degrees Y Tristimulus values.

2. Samples should be measured using the Small Area View (SAV) port size and calibrated to this size before use. Calibration procedures are noted in the CIE L* a* b* test method.

3. Take five samples from four locations of the run for both LDPE and OPP substrates.

4. Take readings for white color samples only.

5. Select the mode for Opacity from the indexes menu and choose Tappi 425 Opacity. Follow the instructions on the screen to proceed with testing. Back each sample with a standard and read 5 times in random places.

Results

Opacity was measured in the laboratory with samples collected from each site. Samples were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Only white printed samples were tested. Table 4-E.13 shows the opacity measurements and standard deviations for these samples. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.13 Opacity Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Average Opacity (%)	Standard Deviation
Solvent-based	LDPE	#S2	5	w	46.66	0.27
				x	48.50	0.40
				y	47.62	0.33
				z	48.28	0.53
			7	w	51.76	0.41
				x	51.22	0.21
				y	51.40	0.43
				z	48.72	0.19
			L5[b]	w	55.52	4.20
				x	50.40	2.02
				z	56.34	4.57
	OPP	#S1	9B	w	50.74	0.37
				x	51.44	1.93
				z	53.90	0.49
Solvent-based	OPP	#S2	10	w	49.24	0.34
				x	47.34	0.26
				y	47.94	0.16
				z	48.24	0.14
			L4	w	40.60	0.76
				x	38.38	1.05
				z	38.62	0.41
UV	LDPE	#U2	6	w	52.68	0.85
				x	52.92	0.36
				y	55.36	0.46
				z	57.60	1.13
UV (no slip)	LDPE	#U1	11	w	55.42	1.00
				x	56.90	0.54
				y	56.52	0.50
				z	56.74	0.48

Table 4-E.13 Opacity Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Average Opacity (%)	Standard Deviation
Water-based	LDPE	#W3	2	w	47.34	0.08
				x	46.62	0.55
				y	46.34	1.15
				z	46.62	0.50
			3	w	57.14	0.24
				x	54.84	0.38
				y	55.00	0.35
				z	52.92	0.38
			L1	w	43.12	0.95
				x	43.06	0.30
				z	43.66	0.74
	OPP	#W1	4	w	51.52	0.34
				x	52.86	0.31
				y	53.46	1.71
				z	52.82	0.33
			L2	w	29.10	0.91
				x	28.68	0.80
				z	27.86	0.81
		#W2	1	w	57.52	0.34
				x	58.20	0.06
				y	56.92	0.29
				z	57.22	0.37
			L3	w	36.74	0.42
				x	37.70	1.64
				z	37.84	0.54
		#W4	9A	w	54.74	0.34
				x	54.22	0.30
				z	53.98	0.17

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]"L" indicates data from a laboratory run.

Rub Resistance

Purpose

The purpose of the dry and wet rub resistance tests is to check the ink's ability to resist being rubbed off of its substrate. The dry and wet rub resistance tests were based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

Sutherland Ink Rub Tester and attachments.
Scoring device (included with the Rub Tester).
Supply of 80 × 80 count bleached muslin cloth which has been found useful in testing wet smear, wet rub, and wet bleed.

Procedure

1. Obtain a 6 inch × 3 inch printed sample which is representative of the rub in ink lay and coverage. When the printed area permits, the 6-inch direction should be cut across the grain of the sheet, but must not cross wrinkles, scores, creases, or other imperfections that would distort the results. Unprinted stock from the same run should be provided in 7½ inch × 2 inch sizes (for dry rub) and 5½ inch × 2 inch sizes (for wet rub). In both cases, cut the longer dimension across the grain of the flexible material.

2. **For dry rub resistance:** Clip a 7½ inch × 2 inch test strip (with a solid printed image 1 inch x 1½ inch centered on the sample) to the 4-pound testing block, with the printing surface away from the rubber pads. Mount the test specimen securely, print side up, on the rubber pad of the base plate. Place the weight over the sample, making sure that one of the 1 inch × 2 inch rubber pads of the test block is over the ink area being tested, and that both surfaces are free of dirt. Preset the tester for 100 strokes, or less if a failure occurs, for a particular printed surface. When the rubs have been completed, examine both the inked surface and the plain surface on the test block for signs of transfer.

3. **For wet rub resistance:** Mount the strips in the same manner as for the dry rub test, using the 2-pound test block. Preset the tester for one rub. Place 2 to 6 drops of distilled water on the printed surface so that they will be covered by the test block. Place the block in position and press the "start" button. After one stroke, examine both surfaces for color transfer. Repeat single strokes until ink failure is noted and record the number of strokes.

4. Record the appearance of the inked surface and/or (as appropriate) the blotter surface. Record the percent of ink transferred, the weight of the test block, and the number of strokes that cause total failure.

Table 4-E.14 summarizes the different conditions for these tests.

Table 4-E.14 Summary of Test Conditions for Dry and Wet Rub Resistance

Test	Test Block (pounds)	Size of Strip (inches)	Suggested Number of Strokes	Strip Material	Contact Time Before Rub
Dry Rub	4	2 × 7½	100	test sheet	0.00
Wet Rub	2	2 × 5½	1 (until failure)	test sheet	0.00

Results

Dry and wet rub resistance was measured in the laboratory with samples collected from each site. Sites 1, 4, 9, and 10 were not tested in the laboratory because the OPP substrate printed at these sites was laminated to another substrate. Samples were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Table 4-E.15 present the results for the dry rub resistance test for the performance demonstration sites and laboratory runs, and Table 4-E.16 presents the results for the wet rub resistance test. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.15 Dry Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Original Density (unitless)	Density After 50 Strokes (unitless)	Percent Retained Density (%)
Solvent-based	LDPE	#S2	5	w	2.06	1.95	94.7
				x	2.06	1.96	95.1
				y	2.05	1.95	95.1
				z	2.12	1.96	92.5
			7	w	1.81	1.75	96.6
				x	1.77	1.65	93.2
				y	1.77	1.75	98.8
				z	1.76	1.65	93.7
			L5[b]	w	1.35	1.28	94.8
				x	0.79	0.78	98.7
				z	0.91	0.90	98.9

Table 4-E.15 Dry Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Original Density (unitless)	Density After 50 Strokes (unitless)	Percent Retained Density (%)
Solvent-based	PE/EVA	#S2	5	w	2.08	2.00	96.2
				x	2.03	1.91	94.1
				y	2.08	1.94	93.3
				z	2.05	1.96	95.6
			7	w	1.65	1.59	96.3
				z	1.64	1.59	96.9
			L7	w	0.75	0.71	94.0
				x	0.78	0.75	96.0
				z	0.82	0.79	97.0
UV	LDPE	#U2	6	w	2.13	1.95	91.5
				x	2.02	1.88	93.6
				y	2.00	1.80	94.5
				z	1.99	1.88	94.5
	PE/EVA	#U2	6	w	1.99	1.89	95.5
				x	1.97	1.80	91.4
				y	1.88	1.84	97.8
				z	1.89	1.84	97.3
		#U3	8	w	1.13	1.11	98.2
				x	1.08	1.10	100.0
				z	1.10	1.07	97.3
UV (no slip)	LDPE	#U1	11	w	2.18	1.88	86.2
				x	1.96	1.80	91.8
				y	2.14	1.86	86.9
				z	2.20	1.91	86.8
Water-based	LDPE	#W3	2	w	1.97	1.82	92.3
				x	1.95	1.80	92.3
				y	1.98	1.86	93.9
				z	2.02	1.93	95.5
			3	w	2.15	1.94	90.2
				x	2.16	2.00	92.6
				y	2.12	1.93	91.0
				z	2.03	1.89	93.0
			L1	w	1.03	1.02	99.0
				x	1.06	1.05	99.1
				z	1.04	1.04	100.0

Table 4-E.15 Dry Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Original Density (unitless)	Density After 50 Strokes (unitless)	Percent Retained Density (%)
	PE/EVA	#W3	2	w	1.67	1.63	97.6
				x	2.14	2.02	94.4
				y	2.08	1.97	94.7
				z	2.04	1.89	92.6
			3	w	1.95	1.90	97.4
				x	1.88	1.75	93.0
				y	1.82	1.75	96.1
				z	1.87	1.80	96.2
Water-based	PE/EVA	#W3	L6	w	0.93	0.88	94.6
				x	0.80	0.79	98.8
				z	0.88	0.85	96.6

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run
[b]"L" indicates data from a laboratory run.

Table 4-E.16 Wet Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Failure at Number of Strokes[b]
Solvent-based	LDPE	#S2	5	w	5
				x	4
				y	4
				z	4
			7	w	5
				x	5
				y	5
				z	5
			L5[c]	w	no failure at 10 strokes
				x	no failure at 10 strokes
				z	no failure at 10 strokes
	PE/EVA	#S2	5	w	3
				x	2
				y	2
				z	2
			7	w	5
				z	5

Table 4-E.16 Wet Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Failure at Number of Strokes[b]
			L7	w	5
				x	6
				z	6
UV	LDPE	#U2	6	w	6
				x	5
				y	5
				z	5
	PE/EVA	#U2	6	w	3
				x	4
				y	5
				z	5
		#U3	8	w	2
				x	3
				z	2
UV (no slip)	LDPE	#U1	11	w	3
				x	2
				y	2
				z	2
Water-based	LDPE	#W3	2	w	8
				x	8
				y	8
				z	8
			3	w	no failure at 10 strokes
				x	no failure at 10 strokes
				y	no failure at 10 strokes
				z	no failure at 10 strokes
			L1	w	no failure at 10 strokes
				x	no failure at 10 strokes
				z	no failure at 10 strokes

Table 4-E.16 Wet Rub Resistance Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Failure at Number of Strokes[b]
	PE/EVA	#W3	2	w	3
				x	3
				y	2
				z	2
			3	w	4
				x	3
				y	3
				z	3
			L6	w	7
				x	6
				z	no failure at 10 strokes

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]A failure represents ink color transferred from the printed substrate to the unprinted substrate. A maximum of 10 strokes were used for the wet rub resistance test.

[c]"L" indicates data from a laboratory run.

Tape Adhesiveness

Purpose

The purpose of the tape adhesiveness test is to check the bond of the dry ink to the substrate. Adequate ink adhesion is critical, because if the ink doesn't adhere well enough, it will not be able to stand up to the normal demands placed on the finished product. The tape adhesiveness test was based on methods developed by Quality Assurance at Sun Chemical Corporation.

Equipment

Printed sample of ink
Adhesive tape (3M — #610)

Procedure

1. Air dry or oven dry the print per standard test procedure.

2. Place a length of adhesive tape (3M — #610) along the length of the print.

3. Hold the print down with one hand and quickly pull the tape off the print. The tape should be pulled at a 90 degree angle to the print, upwards, not against the tape.

4. Observe the tape; there should be no ink removal.

5. Observe the print. Again, there should be no signs of ink removal.

6. If 100% ink removal occurs, verify that the print has been made on the correct side of the substrate.

7. Record the degree of ink removal by estimating the percentage of ink removed.

Results

Tape adhesiveness was measured on site during the demonstration runs, and in the laboratory with samples collected from each site. Sites 1, 4, 9, and 10 were not tested in the laboratory because the OPP substrate printed at these sites was laminated to another substrate. This lamination trapped the ink between the two substrate layers, making it unnecessary to test the ink on the OPP substrate with this method.

Samples for testing were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Due to the aborted run using the PE/EVA substrate at Site 7, samples were only taken from the beginning (w) and the end (z) of the run for testing in the laboratory. Site 8 also had a shorter run for the PE/EVA substrate, so samples were only available at the beginning (w), 30 minutes into run (x), and the end of the run (z).

The laboratory runs at Western Michigan University were shorter in duration than the demonstration runs, so samples for testing were only cut from three locations (w, x, and z).

All ink colors that were printed on each substrate were tested. (White ink was not printed on the white PE/EVA). In the case of a failure, the color(s) of ink removed were listed in the "Comments" column, along with an indication of how much ink was removed.

Table 4-E.17 shows the tape adhesiveness results of samples from each site. When a site number begins with an "L," the data were taken from a laboratory run conducted at Western Michigan University, not from a volunteer printing facility.

Table 4-E.17 Tape Adhesiveness Results for Performance Demonstration Sites and Laboratory Runs

Ink System	Film	Product Line	Site	Location of Sample[a]	Pass/ Fail	Comments
Solvent-based	LDPE	#S2	5	w	P	
				x	P	
				y	P	
				z	P	
			7	w	P	
				x	P	
				y	P	
				z	P	
			L5[b]	w	P	
				x	P	
				z	P	
	PE/EVA	#S2	5	w	F	outline of cyan and magenta was removed
				x	F	outline of cyan and magenta was removed
				y	P	
				z	P	
			7	w	F	cyan and magenta were slightly removed
				z	F	cyan, magenta, and blue were removed
			L7	w	P	
				x	P	
				z	P	
	OPP	#S2	L4	w	P	
				x	P	
				z	P	
UV	LDPE	#U2	6	w	F	white and magenta were removed
				x	F	magenta was slightly removed
				y	P	
				z	P	
UV	PE/EVA	#U2	6	w	F	blue, green, and magenta were removed
				x	F	cyan, magenta, and blue were removed
				y	F	cyan, magenta, and blue were removed
				z	F	all colors were removed
		#U3	8	w	F	cyan was slightly removed
				x	P	
				z	F	cyan and green were slightly removed

Table 4-E.17 Tape Adhesiveness Results for Performance Demonstration Sites and Laboratory Runs (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Pass/ Fail	Comments
UV (no slip)	LDPE	#U1	11	w	P	
				x	P	
				y	P	
				z	P	
Water-based	LDPE	#W3	2	w	P	
				x	P	
				y	P	
				z	P	
			3	w	P	
				x	P	
				y	P	
				z	P	
			L1	w	P	
				x	P	
				z	P	
	PE/EVA	#W3	2	w	P	
				x	F	blue was removed
				y	F	blue was removed
				z	P	
			3	w	P	
				x	P	
				y	P	
				z	F	green was removed
			L6	w	F	all colors were removed
				x	F	all colors were removed
				z	F	all colors were removed
Water-based	OPP	#W2	L3	w	P	
				x	P	
				z	P	
		#W4	L2	w	P	
				x	P	
				z	P	

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]"L" indicates data from a laboratory run.

Trap

Purpose

The purpose of the trap test is to evaluate the efficiency of one ink printed over the top of the next. The trap test was based on methods developed by Western Michigan University.

Equipment

X-Rite 418 densitometer

Procedure

The procedure for measuring trap requires samples to be printed with solid ink densities of magenta, cyan, white, and blue. The trap combinations to be measured were magenta and cyan, and white and blue. However, the densitometer did not get viable results from the white and blue combination. Trap was measured for both 100% tone (solid) and 80% tone samples printed with magenta and cyan.

1. Calibrate the densitometer according to the manufacturer's instructions. For all color references, follow the calibration instructions obtained by pressing the function key and color key together. Using instructions on the instrument, set low (white standard) and high values (black standard) for each color; then read the individual color patches as determined by the instrument. Verify calibration values for each standard patch and make adjustments as necessary.

2. Two samples will be taken from four locations on the press runs for all substrates (LDPE, PE/EVA, OPP).

3. Follow the densitometer instructions for the order in which readings should be performed.

4. The apparent trap is calculated from densitometer readings using the GATF/Preucil trap formula:

$$\text{Apparent trap } [\%] = (D_{op} - D_1) \times 100 / D_2$$

where D_{op} = density of two-color overprint
D_1 = density of first ink down
D_2 = density of second ink down

D_{op}, D_1, and D_2 are measured using the complimentary filter of the second ink down minus the paper.

Results

Trap was measured in the laboratory with samples collected from each site. Samples on samples cut from two locations during the run length as indicated by the following symbols:

w = beginning of run
z = end of run

Table 4-E.18 shows the percent trap for these samples. Trap was measured for 100% tone (solid) and 80% tone areas. The results in Table 4-E.18 are the averages of five measurements taken at each location during the run length. The standard deviation of those five measurements is also shown in the table. The laboratory runs did not have any overprinting using the process colors referred to above, so they were not measured for trap.

Table 4-E.18 Trap Results for Performance Demonstration Sites

Ink System	Film	Product Line	Site	Location of Sample[a]	Tone of Sample (%)	Average Trap (%)	Standard Deviation
Solvent-based	LDPE	#S2	5	w	100	96.6	1.62
					80	99.8	2.79
				z	100	100.0	2.61
					80	99.8	3.71
			7	w	100	100.2	1.17
					80	101.6	1.36
				z	100	98.2	1.17
					80	98.8	1.17
	PE/EVA	#S2	5	w	100	104.2	1.72
					80	100.0	3.52
				z	100	97.4	1.74
					80	97.2	2.64
			7	w	100	93.2	3.82
					80	93.8	3.06
				z	100	92.4	1.36
					80	90.2	1.33
	OPP	#S1	9B	w	100	102.6	1.36
					80	99.0	3.29
				z	100	104.6	2.24
					80	103.8	2.04
		#S2	10	w	100	93.4	6.65
					80	107.6	4.84
				z	100	98.2	4.40
					80	95.8	2.71
UV	LDPE	#U2	6	w	100	88.8	1.72
					80	88.0	1.10
				z	100	89.4	2.80
					80	87.6	3.20
	PE/EVA	#U2	6	w	100	95.0	4.47
					80	91.2	0.75
				z	100	90.2	2.14
					80	90.4	0.49
		#U3	8	w	100	91.4	2.50
					80	94.6	1.62
				z	100	96.2	1.94
					80	97.2	3.60

Table 4-E.18 Trap Results for Performance Demonstration Sites (continued)

Ink System	Film	Product Line	Site	Location of Sample[a]	Tone of Sample (%)	Average Trap (%)	Standard Deviation
UV (no slip)	LDPE	#U1	11	w	100	85.2	4.53
					80	80.6	2.58
				z	100	80.8	1.47
					80	81.0	2.10
Water-based	LDPE	#W3	2	w	100	93.2	5.15
					80	88.0	4.20
				z	100	92.6	2.06
					80	89.6	4.22
			3	w	100	116.4	4.08
					80	105.2	3.31
				z	100	111.6	2.58
					80	109.0	4.05
	PE/EVA	#W3	2	w	100	76.2	1.94
					80	79.6	2.24
				z	100	73.4	3.93
					80	76.8	5.04
			3	w	100	97.6	1.36
					80	105.4	2.24
				z	100	88.4	1.02
					80	78.4	0.80
	OPP	#W1	4	w	100	87.4	1.20
					80	96.8	3.60
				z	100	87.6	1.85
					80	87.6	1.62
		#W2	1	w	100	87.6	3.56
					80	82.0	3.29
				z	100	91.4	1.96
					80	88.4	1.50
		#W4	9A	w	100	88.4	2.50
					80	91.0	5.44
				z	100	87.2	1.47
					80	89.2	1.47

[a]Samples were taken at two locations from the printed sample:
w = beginning of run
z = end of run

Uncured Residue — UV Ink

Purpose

The purpose of the uncured residue test is to determine if uncured residue from UV ink remains on the printed substrate after the final UV curing station. The uncured residue test for UV inks is based on methods developed by Maine Poly Inc.

Equipment

Three glass jars (approximately eight ounces) with lids
Alcohol

Procedure

1. Cut three samples from the roll of printed product.

2. Fill each of the three jars with enough alcohol to fully immerse the printed sample.

3. Place one sample in each jar.

4. After 24 hours, check jar #1. Note if there is any discoloration of the alcohol indicating uncured residue is present.

5. After 48 hours, check jar #2. Note if there is any discoloration of the alcohol.

6. After 72 hours, check jar #3. Note if there is any discoloration of the alcohol.

Results

The uncured residue test was measured in the laboratory with samples collected from Sites 6, 8 and 11. UV ink was not run at any other sites, nor was it used in the laboratory runs performed at Western Michigan University.

The uncured residue test was measured in the laboratory with samples collected from each site. Samples for testing were cut from four locations during the run length as indicated by the following symbols:

w = beginning of run
x = 30 minutes into run
y = 60 minutes into run
z = end of run

Table 4-E.19 presents the results of the uncured residue test for each of the sites. Uncured residue was only measured for green, blue, and white ink, as these colors had the largest areas of coverage. However, uncured residue was only found in blue print. There was no evidence of uncured residue for green and white print. Therefore, the results in Table 4-E.19 are only for blue ink.

Table 4-E.19 Uncured Residue Results for Performance Demonstration Sites

Ink System	Film	Product Line	Site	Location of Sample[a]	Percent of Ink Removed (by weight)[b]
UV	LDPE	#U2	6	w	0.00
				x	0.00
				y	0.00
				z	0.00
	PE/EVA	#U2	6	w	0.00
				x	0.00
				y	0.00
				z	0.00
		#U3	8	w	6.78
				x	7.00
				z	7.14
UV (no slip)	LDPE	#U1	11	w	11.27
				x	9.82
				y	11.51
				z	9.09

[a]Samples were taken at four locations from the printed sample:
w = beginning of the run
x = 30 minutes into the run
y = 60 minutes into the run
z = end of the run

[b]Uncured residue was found in blue print only. No uncured residue was found in green and white print.